

Using Jordanian Natural Zeolite for Capturing Hydrogen Sulfide Gas

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ABSTRACT

In this work a fixed bed column was used to study the adsorption capability of Jordanian natural zeolite for capturing H₂S gas. The effect of pressure, inlet concentration, and zeolite particles size was study, and the breakthrough curves were obtained. The results indicate that Jordanian natural zeolite is an effective material for capturing H₂S gas at a pressure around 5 atm or more and the adsorption capacity is comparable to commercial zeolite. At a pressure of 6atm or more, the saturation adsorption capacity of zeolite is about 0.24 g H₂S/g zeolite. For pressure more than 6 atm the adsorption capacity remains almost the same, and therefore, 6 atm is the suitable operating pressure for Jordanian natural zeolite to capture H₂S.

Keywords: Jordanian natural zeolite, capturing H₂S Gas, adsorption, industrial gas.

INTRODUCTION

Removing acid gasses (H₂S, N₂O, CO, etc.) from industrial gas streams (natural gas, petroleum gas, air streams, etc.) is essential in process industries. Besides pollution, acid gasses when contact with water forms acidic solutions and these acidic solutions cause a high rate of equipment corrosion [Austin 1984]. Several methods are available for removing acid gasses from industrial streams, absorption into amine solution is the predominant technique used for this purpose [Al Jarrah 1997]. The cost of absorption of acid gasses into amine solutions is relatively high and a cheaper method can be developed. Adsorption of acid gasses into solids, especially zeolite, becomes a growing topic of interest in the last years [Ronald 2018]. Commercial zeolite for adsorption is available in the markets. However, due to the physical and chemical treatment of this solid and the restriction of its production to few companies makes the cost of commercial zeolite relatively high in the markets.

Natural zeolite in Jordan is available in huge amounts at northeast, central and south of Jordan as shown in Figure 1. In an extensive study carried out on Jordanian natural zeolites [Ibrahim

1996, AL Dwairi 2007, Reyad 2010] it was found that Jordanian natural zeolite has a surface area comparable to treated commercial zeolites. This great property makes Jordanian natural zeolite a great material for adsorption purposes. The goal of this work is to evaluate Jordanian natural zeolite for capturing H₂S gas from air stream.

EXPERIMENTAL TECHNIQUES

Collections of zeolite samples

Three samples of natural zeolite were collected from Al Hala piles located in south al Tafila/Jordan as shown in Figure 1. The zeolites samples were taken from different locations in AL Hala piles such that all the area is covered. Table 1 shows the chemical composition of these samples.

Preparation of zeolite samples

The zeolite samples are prepared as follows:

1. The samples of natural zeolite are washed by water to remove the dirt.
2. The samples are crushed by jaw crusher and then milled by ball mill.

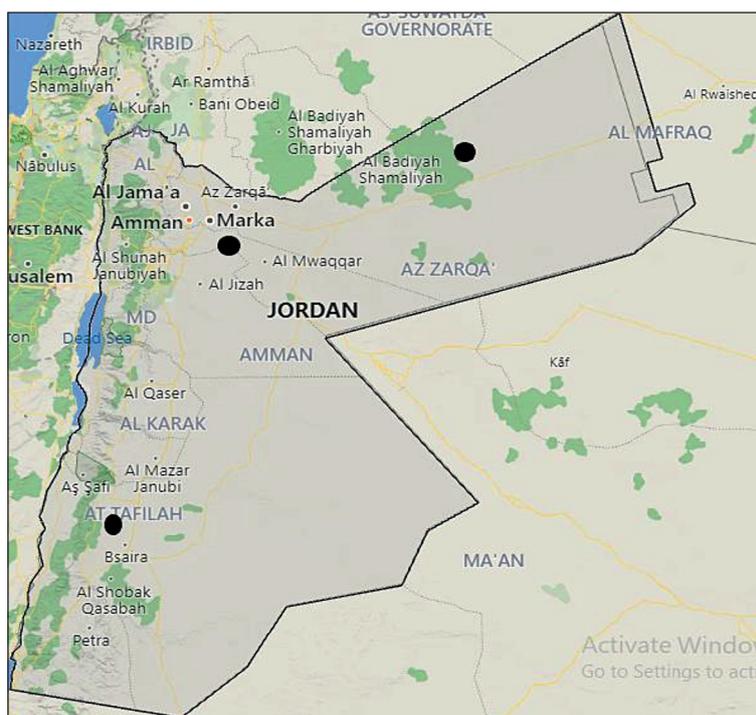


Figure 1. The location (black circles) of natural zeolite in Jordan [Al Dwairi 2007]

Table 1. Chemical composition (wt. %) of natural zeolite taken from Al Hala natural zeolite/Al Tafila [AL Dwairi 2007]

Sample No.	SiO ₂	Na ₂ O	Fe ₂ O ₃	MgO	Al ₂ O ₃	K ₂ O	CaO	MnO	TiO ₂	P ₂ O ₃	CO ₂
1	41.70	0.521	15.50	6.67	15.60	0.94	7.62	0.199	3.28	0.70	6.80
2	40.80	0.670	15.80	7.23	16.90	0.80	6.70	0.210	3.17	0.90	6.10
3	39.60	0.340	16.01	6.89	16.17	0.82	8.10	0.220	3.50	0.81	6.90
Average	40.70	0.510	15.77	6.93	16.223	0.853	7.473	0.210	3.32	0.803	6.60

- The milled natural zeolites samples are wet screened. In this step, the zeolite is separated into sizes and the dirt washed out by water so that the concentration of natural zeolite is increased.
- The samples are dried. After drying the samples are ready for adsorption.

Experimental setup and procedure

Figure 2 shows the experimental apparatus used in this work. Air from the atmosphere is compressed in a storage tank and then filtered to remove the dirt before it mixed with the H₂S gas obtained from gas cylinder. The used H₂S is 99% purity. Valves V1 and V2 are used to adjust the concentration of H₂S. The mixture of gas then compressed with compressor 2 to the required pressure before it enters the bed. The flow rate of the inlet gas mixture is adjusted by vale V3. The concentration of H₂S at the inlet and exit is measured by H₂S gas analyzer (Type: RKI M2A,

RKI Instruments). The operating pressure of the fixed bed can be obtained by closing valve V4 until the pressure build up to the required pressure and then the valve is opened to pass the required flow rate. The fixed bed is 40 cm high by 8 cm inside diameter.

RESULTS AND DISCUSSION

Figures 3–6 show the obtained results using Jordanian natural zeolite to capture H₂S gas. Pressures from 1–8 atm and concentrations from 1–3 mole % inlet H₂S concentration were covered. Three sizes of zeolite 14/20, 35/48 and 200/pan mesh sizes were used. The average of the three samples taken from al Hala piles was plotted in these figures.

Figure 3 shows the exit concentration (C_e) over the inlet concentration (C_a) versus time for different pressures at zeolite size of 35/48. From this figure it can be seen that for pressures up to

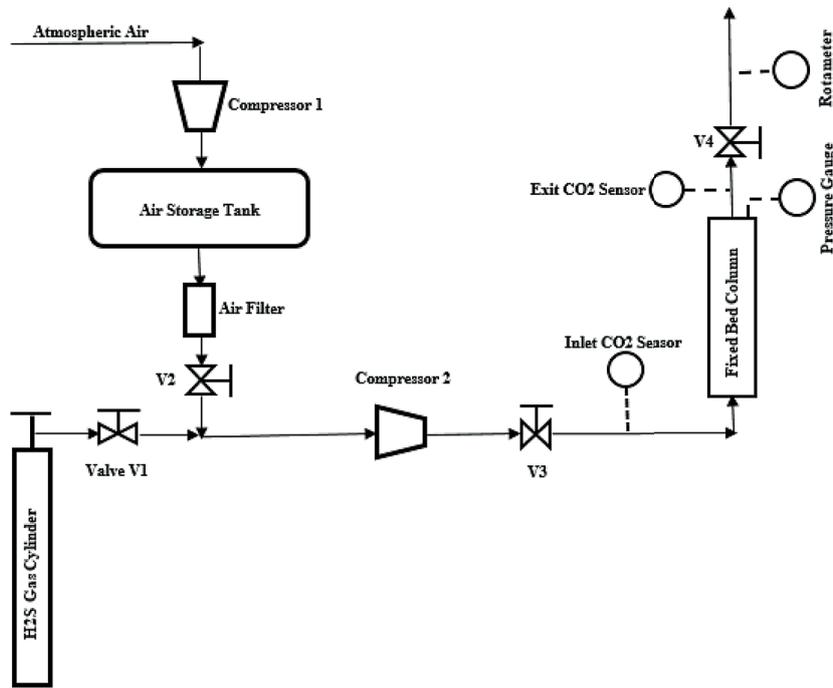


Figure 2. Experimental setup

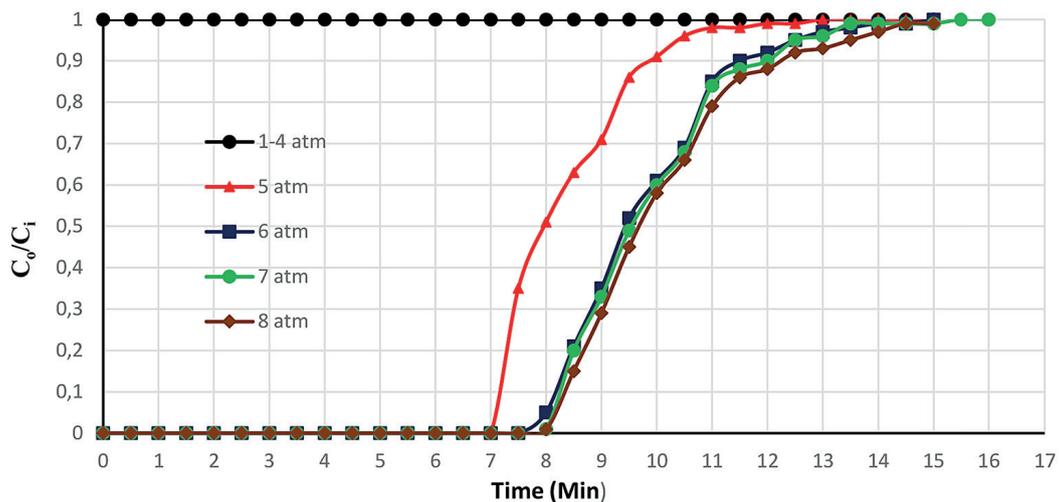


Figure 3. Concentration vs. time at different pressures. Zeolite mesh size 35/48. H₂S inlet concentration 2 moles %

5 atm no adsorption occurs. The adsorption phenomena start to appear for pressures at 5 atm or more. As the pressure increased above 5 atm, the adsorption is enhanced up to 6 atm and further increasing in pressure results in weak enhancement in adsorption. Therefore, pressures about 6 atm is the suitable pressure for adsorption using Jordanian natural zeolite to capture H₂S.

Figure 4 shows the effect of zeolite particles size on the adsorption, as the particles size decreases the adsorption is significantly increases. This is because as the particles size decreased, the

surface area increased, and therefore, more sites for adsorption are created. Figure 5 shows the effect of inlet H₂S concentration on adsorption. As expected, as the concentration increased, the breakthrough time becomes shorter.

Finally, Figure 6 shows the adsorption capacity of Jordanian natural zeolite versus pressure. The total amount of H₂S captured by the zeolite is given by [Warren et.al. 1993].

$$W_{sat} = \frac{Q \dot{C}_l M}{w} \int_0^{t_e} \left(1 - \frac{C_e}{C_l}\right) dt \quad (1)$$

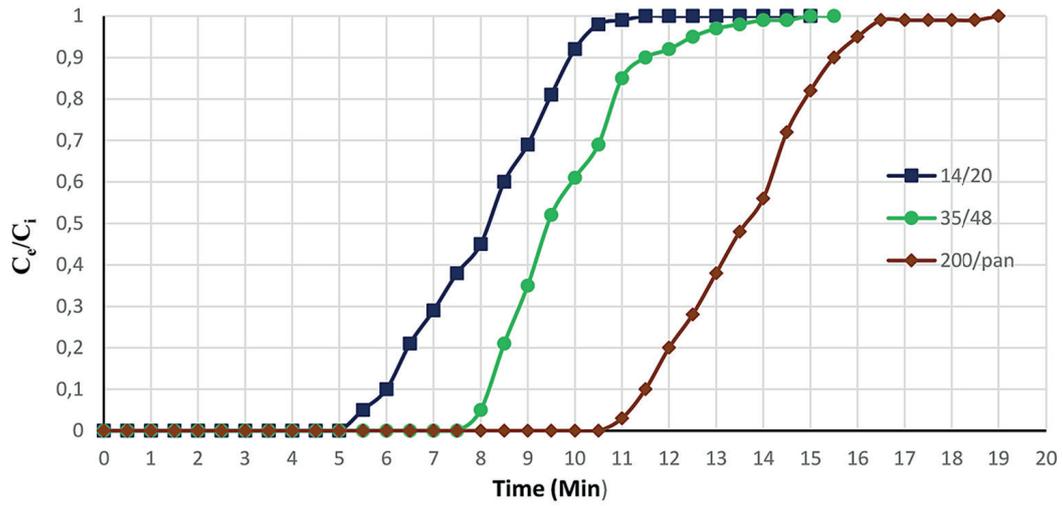


Figure 4. Concentration vs. time at different zeolite sizes. Pressure 6 atm. H₂S inlet concentration 2 mole %

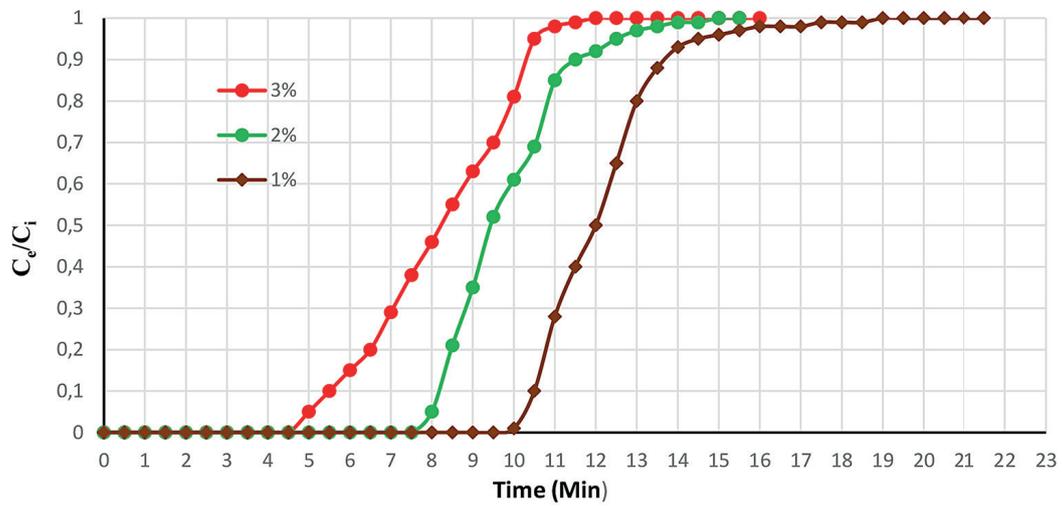


Figure 5. Concentration vs. time at different CO₂ inlet concentration. Zeolite mesh size 35/48. Bed operating pressure 6 atm

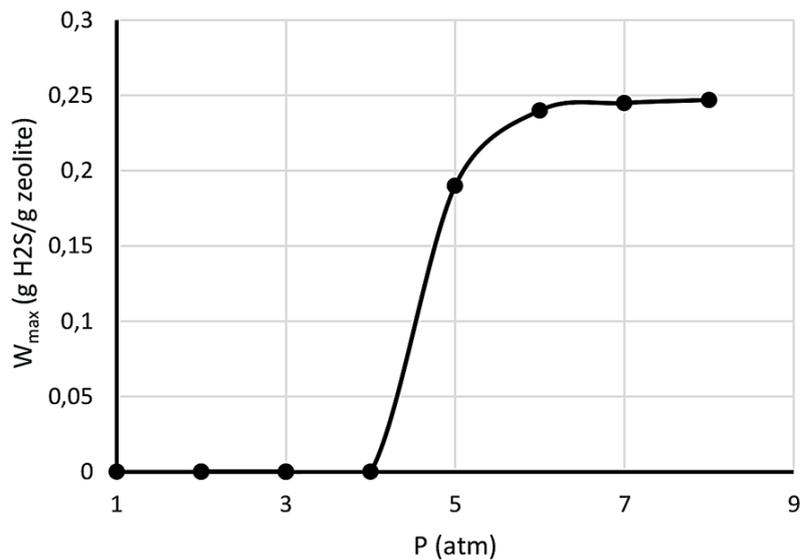


Figure 6. Adsorption Capacity versus Pressure of Jordanian Natural Zeolite for Capturing H₂S

where: W_{sat} – the adsorption capacity at saturation;
 Q – the volumetric flow rate;
 C_i – the inlet molar concentration of H_2S ;
 C_e – the exit molar concentration of H_2S ;
 M – the molecular weight of H_2S , and w
 is the weight of zeolite in the bed.

The integration in equation 1 is the area above the breakthrough curve.

Figure 6 shows that no adsorption exist below 4 atm. The adsorption starts at a pressure around 5 atm or more and enhanced further with increasing pressure up to 6 atm. For pressure more than 6 atm W_{sat} is very weakly increased with pressure.

At the end an explanation is suggested about why at a pressure less than 5 atm no adsorption occurs while it increased significantly from 5–6 atm and then it becomes weakly increased with pressure after 6 atm. Zeolite has a honeycomb-like structure with opening a little larger than the dimension of H_2S molecule [Ibrahim 1996, Al Dwairi 2007, Reyad 2010]. At a pressure less than 5 atm the pressure force on H_2S molecule is not sufficient to push the H_2S molecule inside the structure of zeolite and capture it. At a pressure of 5 atm or more, the pressure force becomes sufficient to push the H_2S molecule inside the structure of zeolite and capture it. Increasing the pressure from 5–6 atm enables more H_2S molecules to penetrate and captured by the zeolite, that's why the adsorption enhanced from 5–6 atm. After 6 atm approximately all the sites for capturing CO_2 are filled but few of them which are hard to reach by H_2S is still empty and further increase in the pressure enables few more H_2S molecule to reach and captured by these sites, after these sites are filled, further increase in pressure results in no effect because all the sites now are filled.

CONCLUSION

The results indicate that Jordanian natural zeolites can be efficiently used to capture H_2S at a pressure of 5 atm or more. For pressure less than 5 atm, no adsorption occurs. For a pressure of 6 atm or more, the saturation adsorption capacity of zeolite is about 0.24 g H_2S /g zeolite.

Further increase in pressure results in no or weak enhancement in adsorption. Therefore, pressure around 6 atm is the best for Jordanian natural zeolite to capture H_2S .

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